water

Article

Water and Energy Sustainability of Swimming Pools: A Case Model on the Costa Brava, Catalonia

Juan-Jose Gomez-Guillen [1,*], Núria Arimany-Serrat [1], David Tapias Baqué [2] and David Giménez [2]

[1] University of Vic–Central University of Catalonia, Faculty of Business and Communication Studies, 08500 Vic, Spain; nuria.arimany@uvic.cat
[2] Fluidra, 08174 Sant Cugat del Vallès, Spain; dtpapias@fluidra.com (D.T.B.); dgimenez@fluidra.com (D.G.)
* Correspondence: juanjose.gomez@uvic.cat

Abstract: The aim of this research is to propose a more sustainable swimming pool, in terms of water and energy, in the Costa Brava area. The methodology is focused on the creation of a descriptive water and energy model for swimming pools and their monitoring, to propose the transition to a more sustainable swimming pool, in the context of climate change. The research is characterized by an exploratory, descriptive, and simulation approach to adapt swimming pools to the new requirements. Two significant impacts are highlighted from the perspective of water and energy stress—the carbon footprint, related to environmental impact and climate change, and the new business models of the sector, for a more sustainable tourism, with more sustainable pools. In terms of water balance, evaporation is an important variable and there are technical solutions on the market to control it, such as the use of covers. Furthermore, the modeling and simulation carried out helps to calculate the variable as a tool for improvement. For energy balance, in outdoor pools, pumping is an important variable and there are technologies, such as speed variation, that make it possible to reduce this. Furthermore, it should be noted that this research represents an important tool for the improvement of sustainability and operability for the various stakeholders, especially owners and governments, to face climate change, which is becoming increasingly critical for many regions.

Keywords: environmental sustainability; environmental impact; swimming pools; climate change; tourism; hotels; hotel industry; Costa Brava

check for updates

Citation: Gomez-Guillen, J.-J.; Arimany-Serrat, N.; Tapias Baqué, D.; Giménez, D. Water and Energy Sustainability of Swimming Pools: A Case Model on the Costa Brava, Catalonia. *Water* **2024**, *16*, 1158. https://doi.org/10.3390/w16081158

Academic Editor: Carmen Teodosiu

Received: 9 March 2024
Revised: 10 April 2024
Accepted: 18 April 2024
Published: 19 April 2024

1. Introduction

The experiences resultant from the COVID-19 pandemic and climate change represent an unprecedented challenge for ecosystems and societies at a global level. Climate change significantly affects areas with a Mediterranean climate and a high tourist density, such as the Costa Brava in Catalonia [1–7]. These areas face unique challenges due to the importance and the large mass of tourism they receive, with the need to manage water and energy resources efficiently [8–10].

In Catalonia, and particularly the Costa Brava, a tourist area that experiences a large arrival of visitors during the summer period, the significant increase in population causes major complications in the management of resources and the handling of the produced waste. This increase in population, which multiplies several times the usual number of inhabitants, leads to a higher energy and water consumption, increased mobility problems, and waste generation, with a significant environmental impact [11–13].

Hotel swimming pools play a crucial role in the tourism offerings of these hotel establishments [14–16], since they are one of the sector's main attractions for clients and offer a space for recreation and relaxation that complements the visitors' experience.

Swimming pool water, exposed to a wide variety of contaminants, such as air and environmental pollutants; contaminants introduced by bathers; and their subsequent microbial growth, requires strict physicochemical treatment to ensure water safety, health, and quality [17]. This includes filtration to remove solids and the use of chemicals to neutralize pathogenic microorganisms and maintain the water balance. Public pools are subject to higher levels of government regulation and supervision, due to the higher number of users [18]. These regulations require specific water quality standards and regular testing and maintenance protocols to protect public health, by ensuring that water treatment processes meet established safety criteria [19], and must adapt to new scenarios by implementing technologies and practices that reduce their environmental footprint [12,20–22].

Catalonia is currently experiencing a major drought period, with both ecological and socio-economic challenges. The decrease in rainfall in the region, partly attributed to climate change, has led to a critical decrease in the available water levels; the regional Government (Generalitat de Catalunya) has decreed a state of emergency, due to hydrological drought. This drought decree has imposed a series of staggered restrictions in three emergency sub-phases, which include limitations on the human consumption of water, as well as on agriculture, livestock, and industry. In addition, the initiation of new water-intensive projects has been prohibited.

In the specific case of swimming pools, indoor pools registered in the sports equipment database of the Generalitat de Catalunya can only replace the water lost daily, but these pools cannot be filled from scratch. Sports clubs that use pools for federated sports may also refill water. However, in the private and tourist sector, private swimming pools, as well as swimming pools in hotels, campsites, and water parks, cannot be refilled [23,24].

The aim of this research is to propose a more sustainable swimming pool, in terms of water and energy in the Costa Brava area, using contrasted indicators, by means of a descriptive model of swimming pools, and a simulation that monitors swimming pools in the area, in order to determine key actions and measures to tackle climate change. This area has a Mediterranean climate, with regular periods of drought [25–27], and has a large number of swimming pools, as a major tourist asset in the hotel sector. Another relevant issue related to the sustainability of swimming pools is the reduction in chemicals and waste, which will be analyzed in future research.

Consequently, the situation promotes considerable challenges in the tourism sector, as water scarcity not only limits the recreational offer related to swimming pools, but also calls for a re-evaluation of practices and strategies to ensure sustainability and environmental responsibility in the sector. It is, therefore, imperative to explore how swimming pools become more sustainable to mitigate their environmental impact. This includes water savings, through reduced evaporation and water recycling, and energy efficiency, through the use of renewable energy and more efficient systems. These measures not only respond to the need to conserve natural resources, but also to the economic pressure resulting from the energy crisis and they present an opportunity to innovate and transform the Catalan tourism industry towards a more efficient business model.

The sustainability of swimming pools is an important issue and correlates with climate change, so it is imperative to innovate more efficient pools in the use of limited resources such as water and energy [20,28]. The research in this field is evolving, as pandemics, climate change, and the technological revolution are changing the management systems of organizations [7,28–31]. The literature review highlights the sustainable management of swimming pools, focusing on water stress, energy stress [17,30–32], and applicable legislation [19,32–34]. It is worth remarking that the literature indicates that climate change will drive new research to continuously improve swimming pools, in the face of these new scenarios [35,36]. On the other hand, this review addresses the concerns of the hotel sector regarding technological and behavioral changes, in the context of governmental legislation to control and mitigate the effects of drought [11,12,37–41].

A significant problem in the area analyzed is water evaporation [3,42] and another is energy stress, due to access and the high cost of energy due to geopolitical conditions [36]. It is highlighted that green and renewable energy does not have a carbon footprint, unlike other energy alternatives [21,40,43,44].

The tourism sector under study, in areas with a Mediterranean climate, shows a growing sensitivity towards environmental sustainability and seeks to innovate in the operation of swimming pools in hotel establishments, to respect the water and energy balance [9,45,46]. The Costa Brava and the Catalan tourism sector, being large consumers of water and energy, are seeking efficiency in the use of these resources [47–49].

During drought periods, such as the current one, concerns in the hotel sector increase and the will of the sector is to mitigate the effects of the drought, in line with government regulations [23]. To tackle the problems arising from pool water balance and water evaporation (with a high evaporation rate due to climate change), simulation models are applied to predict the amount of water lost through evaporation, as a key environmental parameter [3,42,50–56].

Another measure, which improves energy and water consumption, is rainwater harvesting [28]. Pool design also influences water and energy stress and there are studies that simulate evaporation, considering variables such as water temperature, relative humidity, and pool occupancy [57–61]. Consequently, the water and energy challenges of swimming pools are increasingly being assessed [2,9,62]. In particular, research at the energy level focuses on filtration during recirculation and disinfection for the healthiness of the pool; others concern water stress in the filter washing process and water recovery, with technologies that simulate evaporation, using various variables, such as temperature, relative humidity, occupancy, and other parameters [51,52,63–69]. The studies related to filtration during recirculation and disinfection to ensure pool sanitation [70] and the studies of water stress in the filter cleaning process [29,71,72] and water recovery [73–76] are of great importance in the research presented here. Regarding energy stress, water heating is a major challenge and air conditioning and dehumidification entail significant energy expenditure [36,77–79]. To improve this expenditure, efficient heating with appropriate heat pumps is essential [80,81]. To this end, there are energy simulation models that aim to improve the energy efficiency of swimming pools [28,82–84]. Specifically, energy stress drives efficient optimization studies through the prediction of energy consumption and savings, as well as the improvement of the energy cycle of swimming pools [85–90]. Regarding the use of renewable energy, such as solar energy, for heating swimming pools, there are studies that seek to achieve an energy balance between all the alternatives [35,36,43,78,85,91–94].

It should be highlighted that descriptive water and energy models are available in the literature [60,84,85] which have contributed to the consideration of the descriptive models presented in the research under study.

Thus, the issues of concern in the literature, at the level of water stress, are evaporation [42,50–54,56,63,65–69,83], filter backwashing [29,61,72,75,76], and water reuse and disinfection [71,74,76]. Regarding energy stress, the literature is based on energy consumption and cost [20,28,30,77,85,86,90], heating [31,78,79,81], simulation models and applicable technology [35,58,60,65,84,86,89], solar systems to reduce consumption [35,36,43,91–94], and carbon footprint [12,20–22].

The literature review highlights two significant impacts in the field of swimming pools from the perspective of water and energy stress—the carbon footprint, related to environmental impact and climate change, and the new business models of the hotel sector, at a social level, for more sustainable tourism, with more sustainable swimming pools [95–99].

2. Materials and Methods

The methodology of this research focuses on the creation of a descriptive water and energy model for swimming pools and the monitoring of three swimming pools in the area under study, to propose the transition to a more sustainable swimming pool, in the context of climate change. This research is characterized by an exploratory, descriptive, and simulation approach to adapt the pools to the new environmental scenarios. The monitoring of the three pools makes it possible to evaluate the consumption of resources, with a view to increasing water and energy efficiency to reduce the environmental impact.

After the introduction, the literature review and the methodology of the study are presented, the data are analyzed, and the results obtained are presented, together with a discussion of the results, to enhance the sustainability of swimming pools in terms of water and energy, using contrasted indicators, with actions, in this respect, to tackle climate change. Finally, the conclusions of this study, its limitations, and future lines of research are presented.

2.1. Hydraulic Model of the Pool

In order to establish a water model that reflects the balance between the volumes of water entering and leaving a pool, Figure 1 illustrates a schematic of the water recirculation line, with its main components and the inflows and outflows. This analysis will focus on the water dynamics, leaving the study of the chemical water treatment processes for a later investigation. In the proposed scheme of the hydraulic circuit, the light blue arrows will symbolize the variations in the volume of water contained in the pool.

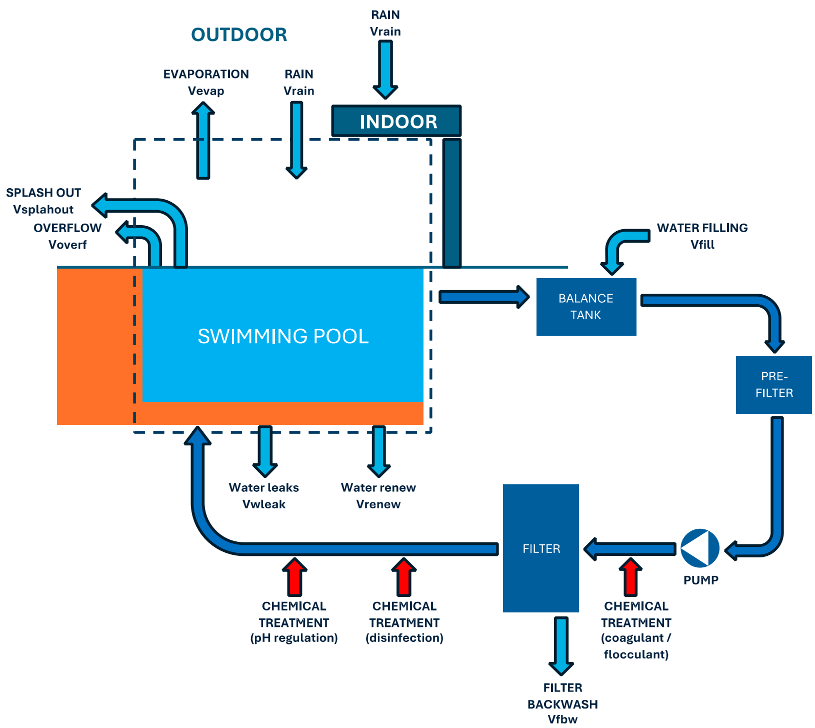

Figure 1. A schematic representation of the hydraulic circuit of a swimming pool (Source: Own elaboration based on the academic and industry literature).

Once this water model has been established, the water consumption of the facility can be calculated. With this information, the necessary measures to reduce water consumption will be determined, which is essential for both the environmental sustainability and operational efficiency of the pools. These measures could include the implementation of more efficient recirculation systems, the adoption of water treatment technologies that minimize filtration and evaporation losses, and the integration of water management practices that promote the rational use of water.

This holistic approach not only helps to conserve water, an increasingly limited resource, but can also offer significant economic benefits by reducing the operational costs associated with filling and maintaining pools. This approach isolates the variables that directly affect the water balance and facilitates understanding of the physical processes that govern the recirculation system.

Table 1 sets out and explains the main variables that make up the hydraulic circuit of a swimming pool, a fundamental aspect for the maintenance and efficient management of water. These variables cover not only the volume of water moving through the filtration and recirculation system, but also important aspects such as freshwater addition rates, evaporation, usage, and cleaning losses. Understanding these components is vital to ensure optimal water quality, while maintaining the efficient use of water and energy resources.

Table 1. Variables of the hydraulic circuit of a swimming pool (Source: Own elaboration).

Name	Definition	Acronym
Water filling	Refilling of pool renovation water. This water inlet is used to compensate for water losses in addition to the water loss.	V_{fill}
Filter backwash	To carry out maintenance and cleaning operations on filters, water is sent in the opposite direction to the filter operation. This cleaning water is sent to the sewage system.	V_{fbw}
Water renew	According to the legislation of some countries, a minimum water renewal with fresh water is required to ensure that the water quality is suitable and does not represent a problem for bathers.	V_{renew}
Water leaks	Water leaks due to lack of watertightness of the pool or the pool's hydraulic system.	V_{wleak}
Overflow	Water leaks from the pool overflow system.	V_{overf}
Splash out	Water losses due to splashing, use, and interaction with users. These quantities are generally considered within the evaporation estimate for occupied pools.	Vsplahout
Evaporation	Water losses due to evaporation from the pool surface.	V_{evap}
Rain	Rainwater contribution, in the case of outdoor open-air pools, corresponds to the water collected from the total surface of the pool. In the case of indoor pools, it is necessary for the installation to have a rainwater collection system, but, in some countries, this system is not permitted by law.	V_{rain}

To calculate the water balance of swimming pools, it is necessary to consider the variables in Table 1 and the variables that are input and output of the pool system. Equation (1) determines the variation of the volume of water in the pool system (V_{wp}) over time:

$$\frac{dV_{wp}}{dt} = V_{fill} + V_{rain} - V_{fbw} - V_{evap} - V_{renew} - V_{wleak} - V_{overf} - V_{splahout} \tag{1}$$

This equation could be simplified in the case that a stationary aquatic system in balance is considered, which, under normal conditions, is the normal condition for swimming pools and, where the filling water compensates the water losses of the rest of the variables, Equation (2) responds to this simplification:

$$V_{fill} = V_{fbw} + V_{evap} + V_{renew} + V_{wleak} + V_{overf} + V_{splahout} - V_{rain} \tag{2}$$

The discussion on these hydraulic variables is developed when considering their direct impact on the environmental sustainability of aquatic facilities. For example, a high evaporation rate not only increases the demand for freshwater, but also increases energy consumption, due to the need to heat more water to replace the lost water, in the case of indoor pools with water heating systems. Furthermore, a detailed understanding of filtration and usage losses can lead to the implementation of more efficient strategies, such as coating systems that reduce evaporation or advanced filtration technologies that minimize the need for frequent water replacement.

Additionally, this detailed analysis of the variables of the hydraulic circuit underlines the importance of adopting an integrated approach to water management in swimming pools, which not only considers the operational and maintenance aspects, but also the environmental and economic impacts of these practices. The adoption of innovative and sustainable technologies, together with efficient management practices, can lead to a significant reduction in water consumption, thus contributing to the overall sustainability of aquatic facilities.

2.2. Energy Model of the Pool

Figure 2 below depicts a schematic of the energy balance in swimming pools, a critical component in understanding how energy resources are managed and can be optimized in these facilities. This diagram covers various factors that affect energy consumption and conservation, such as water heating, filtering and pumping systems, thermal losses through evaporation, and thermal transmission to the environment. The lighting system is not considered in this scheme.

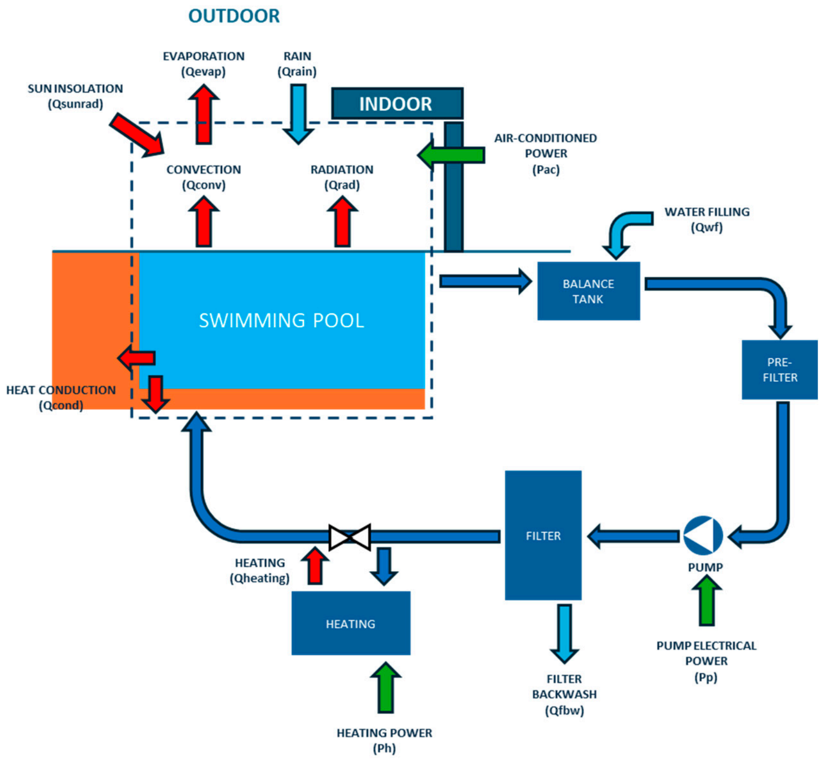

Figure 2. A schematic representation of energy balance of a swimming pool (Source: Own elaboration based on the academic and industry literature).

The energy balance of a swimming pool is defined as the relationship between the energy supplied to the system and the energy lost or used by it. This balance is fundamental for implementing energy efficiency and sustainability measures, considering aspects such as the following:

1. Thermal losses: Evaporation of water is a significant source of heat loss in swimming pools, especially in outdoor pools. The use of covers or dehumidification systems in indoor pools can control these losses. In addition, the thermal insulation of the pool and minimizing transmission losses through the pool walls and bottom are key strategies to maintain a favorable energy balance.
2. Water heating: The energy required to heat pool water represents one of the largest energy demands. The use of more efficient heating systems, such as heat pumps, solar thermal systems or grey water heat recovery, can significantly reduce this consumption.
3. Filtration and pumping systems: These systems are essential for maintaining water quality, but they also consume energy. Optimizing their operation and using energy-efficient equipment can reduce the associated energy costs.
4. Air conditioning system: The air conditioning and heat treatment system in indoor swimming pools controls temperature, humidity, and air quality, ensuring comfort and protecting the infrastructure.

The implementation of practices and technologies that improve the energy balance not only contributes to environmental sustainability, but also represents a reduction in the operating costs of swimming pools. The detailed evaluation of the energy balance scheme, as shown in Figure 2, is an essential step towards understanding and improving energy efficiency in these facilities.

Table 2 shows the main variables for defining the heat balance of swimming pools. These variables refer both to the heat balance and its elements, as well as to the energy required for the correct operation of the system.

Table 2. Variables of the energy balance of a swimming pool (Source: Own elaboration).

Name	Definition	Acronym
Water filling	In case the pool has a water heating system, this variable corresponds to the heat demand due to bringing the pool renovation water from the source temperature to the required pool temperature.	Q_{wf}
Filter backwash	As in the previous case, if the pool has a water heating system, this variable corresponds to the heat loss of the backwash water.	Q_{fbw}
Heating	Corresponds to the heat value provided by the water heating system to maintain the pool water volume according to the temperature reference.	$Q_{heating}$
Heat conduction	Heat losses, due to conduction losses, through the pool surface and through the pool walls and floor.	Q_{cond}
Convection	Heat losses, due to convective heat transfer, due to heat transfer between the water surface and the outside and inside air.	Q_{conv}
Radiation	Heat losses due to radiative heat transfer between the water surface and other surrounding surfaces, such as the walls or the sky.	Q_{rad}
Evaporation	Heat losses due to evaporation (phase change from liquid to gas) of water on the pool surface.	Q_{evap}
Rain	Heat demand due to making the rainwater entering the pool from the source temperature to the required temperature in the pool.	Q_{rain}
Sun insolation	Heat from direct solar radiation.	Q_{sunrad}
Pump electrical power	Energy needs to carry out the filtration and water treatment of the pool.	P_p
Heating Power	Energy requirements for the thermal treatment of swimming pool water.	P_h
Air-conditioned power	In the case of indoor pools this variable corresponds to the energy needs for the air treatment (dehumidification and thermal conditioning) of the pool.	P_{ac}

To calculate the energy balance of swimming pools, it is necessary to consider the variables in Table 2 and to consider the input and output variables of the pool system. Equation (3) represents the heat variation of the pool water system for stationary conditions, where all the heat input is used to compensate for the heat losses of the system:

$$Q_{gain} - Q_{loss} = 0 \tag{3}$$

where, on the one hand, Q_{wf} corresponds to the heat necessary to compensate the water renewal of the pool and, thus, compensate the heat losses due to filter cleaning and other water losses, as can be seen in the water balance above.

So, Q_{gain} (heat gained) and Q_{loss} (heat lost) would be as follows in Equation (4).

$$Q_{gain} = Q_{heating} + Q_{rad} \tag{4}$$

$$Q_{loss} = Q_{cond} + Q_{conv} + Q_{evap} + Q_{rad} + Q_{wf} \tag{5}$$

$$Q_{heating} = Q_{cond} + Q_{conv} + Q_{evap} + Q_{rad} + Q_{wf} - Q_{rad} \tag{6}$$

Equation (6) is the general formula for the necessary heat to be provided by the pool water heating system through the energy consumption, P_p.

The energy needs to carry out the filtration and water treatment of the pool depend on the volume of the pool and the recirculation time and, with these parameters, the filtration flow rate is calculated to select the pump, as can be seen in Equation (7).

$$Total\ recirculated\ flow\ rate\ \left(\mathrm{m^3/h}\right) = Q_{total}\ \left(\mathrm{m^3/h}\right) = \frac{Pools\ water\ volume\ \left(\mathrm{m^3}\right)}{Recirculation\ time\ (\mathrm{h})} \tag{7}$$

The following equation is used to calculate the pump power:

$$P_b = \gamma \, Q_{total} \, h_b \tag{8}$$

where

P_b *is the hydraulic power of the pump, in* W
γ *is the specific weight of the fluid* $\left(9800\,\frac{\mathrm{N}}{\mathrm{m}^3}\ for\ water\right)$
Q_{total} *is the recirculated flow rate, in* $\frac{\mathrm{m}^3}{\mathrm{s}}$
h_b *is the manometric head (pressure) at which the pump works, in* m.w.c. *(metres of water column)*

The next step is to calculate the electrical power consumed by the filtration pump, which is calculated using Equation (8).

$$P_1 = P_{input} = \frac{P_b}{\eta_b \, \eta_m} \tag{9}$$

where

$P_1 = P_{input}$ *is the input power from the electricity mains, in* kW
P_b *is the hydraulic power, in* kW
η_b *is the pump efficiency*
η_m *is the motor efficiency*

Regarding the calculation of the thermal treatment and humidity needs of the pool, this study does not consider these needs and this variable will be studied in future research.

2.3. Experimental Design of Monitoring and Simulation in Swimming Pools

In the process of designing and implementing an experimental study aimed at optimizing swimming pools and their water use, special attention has been paid to the specific characteristics of hotel swimming pools located on the Costa Brava. Given that most of these pools are outdoor and do not have water heating systems, water resource management emerges as a critical challenge. This challenge is increased in the current context of the drought crisis in Catalonia, a phenomenon that, influenced by climate change, is expected to become more recurrent in the future. It is important to bear in mind that the various simulation models for predicting the amount of water lost through evaporation are empirical, with key environmental parameters [3,41,49–55].

In this study, the aim is to model the water balance of a swimming pool and, if we concentrate on evaporation through simulation, based on the initial monitoring of three swimming pools from July 2023, anticipating the incorporation of more installations in the future.

The objective is to identify which simplified evaporation calculation model aligns most closely with actual measurements. This validation process relies on two sets of meteorological data—one coming from a weather station installed on-site next to one of the pools and the other one obtained through an external API (Wunderground—https://www.wunderground.com/ (accessed on 17 April 2024)).

The use of local data is indispensable for accurate and contextualized measurements; however, the integration of data from an external API such as Wunderground presents an opportunity to project evaporation conditions at multiple locations without the need to implement additional meteorological infrastructure at each site. This strategy would allow for the anticipation of evaporation rates and, therefore, facilitate informed decision making regarding the implementation of measures to minimize water losses and optimize the operational management of pools.

This methodological approach not only demonstrates the application of simulation and data analysis technologies in the field of aquatic resource management, but also underlines the importance of innovation in the search for sustainable and efficient solutions to the operational and environmental challenges associated with pool maintenance.

For pool evaporation modeling in academia, as already indicated in the literature review section, several predictive models of water evaporation in pools and other bodies of surface water, based on experimental data, have been recognized [50–52,54–56]. It is important to note that the various simulation models aimed at predicting the amount of water lost through evaporation are based on empirical approaches. These models evaluate the amount of water evaporated as a function of environmental parameters.

Two methods with a long academic tradition have been used to calculate the evaporation rate in the experiment.

On the one hand, we have the Penman equation [54]:

$$E_0 = \frac{\frac{700T_m}{100-A} + 15(T - T_D)}{(80 - T)} \left({}^{\text{mm}}/_{\text{day}} \right) \tag{10}$$

where

$$T_m = T + 0.006\,h \tag{11}$$

E_0 is the evaporation value, in mm/day per unit area of the pool.
T is the average temperature.
A is the latitude, in degree of the location.
T_D is the temperature of Dew.
h is the height above sea level of the location.

On the other hand, the formula described by Meyer in his study "*Evaporation of Surface Water Bodies. A Compendium of Water Resources Technology*" (1915), which is, even today, one of the most widely used methods for evaluating the evaporation of surface water bodies. The formula of this study is described in Equation (10).

$$E_0 = K_M(e_w - e_a)\left(1 + \frac{u_9}{16}\right)\left({}^{\text{mm}}/_{\text{dia}} \right) \tag{12}$$

where

$$u_h = Ch^{1/7} \tag{13}$$

$$\frac{e_a}{e_w} = Relative\ humidity\ (\%) \tag{14}$$

E_0 is the evaporation value, in mm/day per unit area.
K_M is a coefficient that depends on the depth of the water body (0.36 for deep water bodies and 0.5 for shallow or shallow water bodies). For swimming pools, 0.5 is used as the coefficient K_M.
e_a is the saturation pressure of water vapour at water surface temperature (mmHg).
e_w is the saturation pressure of water vapour above the water surface at a given height (mmHg).
u_9 is the daily average wind speed at a height of 9 m above the surface (km/h).

With these premises, the installations are monitored and simulated. The graphs of the installations reflect the results of the simulation for a period of approximately 1 year.

Figure 3 shows the data collection and simulation of installation 1, on a daily basis, in liters.

The punctual nature of the daily evaporation values makes their direct interpretation difficult; therefore, the use of cumulative values over a period of time is recommended for a more comprehensive understanding of the phenomenon. This is illustrated in Figure 4, where the cumulative data for the same installation is displayed. The cumulative representation allows for an appreciation of the underlying trends and patterns in evaporation behavior, consequently facilitating analysis and decision making based on a longer time frame.

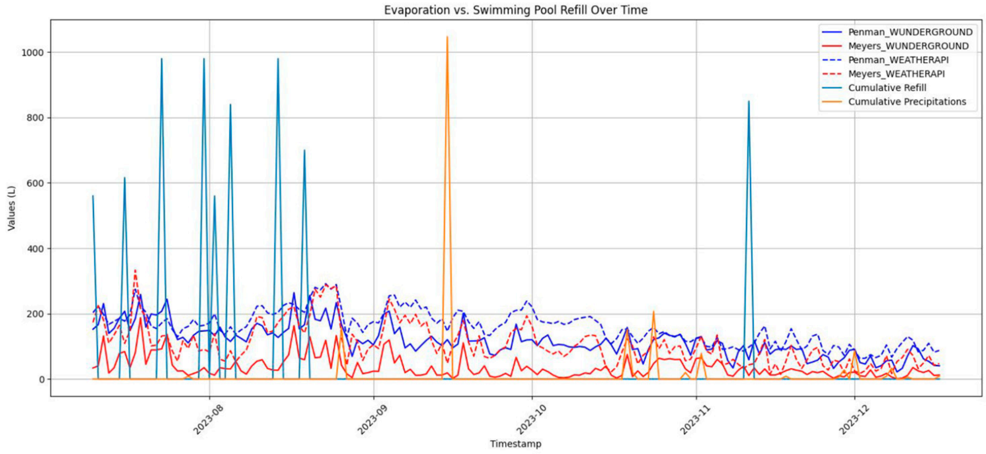

Figure 3. Hydric balance of installation 1 (daily values) (Source: Simulation values).

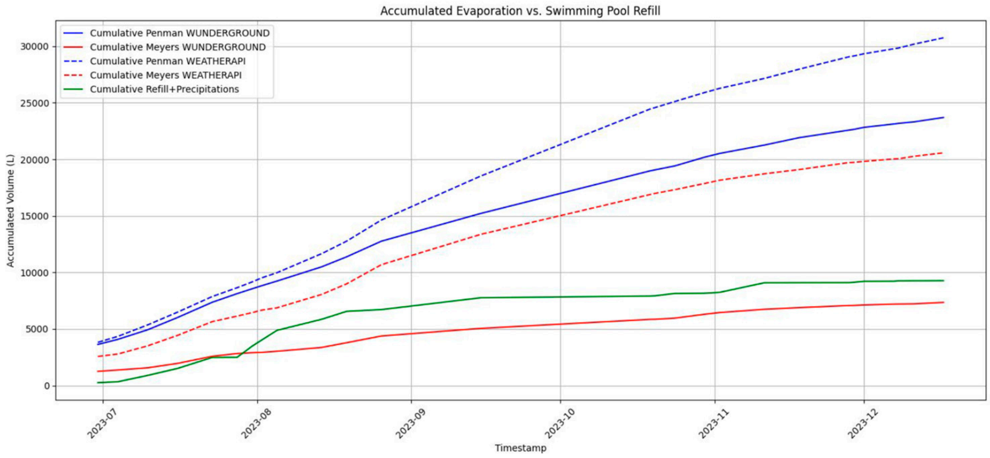

Figure 4. Hydric balance of installation 1 (cumulative values) (Source: Simulation values).

Similarly, Figure 5 shows the daily collection data for installation 2.

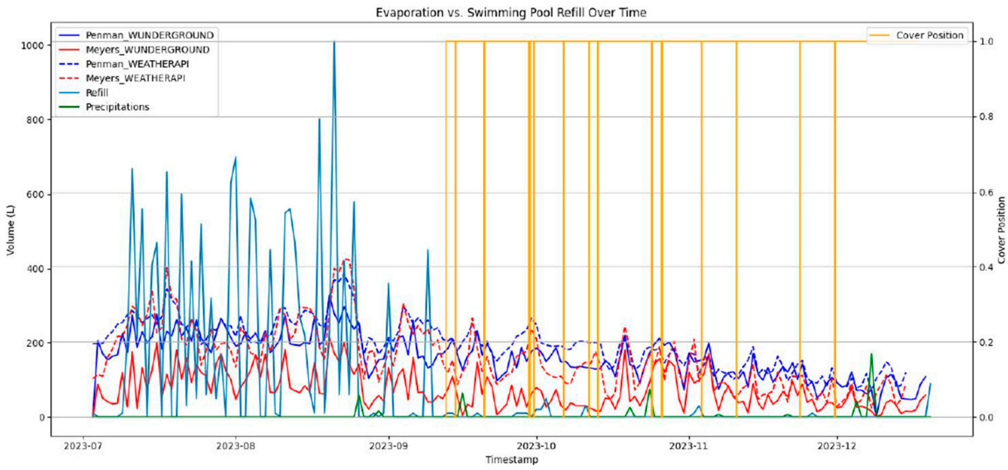

Figure 5. Hydric balance of installation 2 (daily values) (Source: Simulation values).

Figure 6 shows the cumulative data for installation 2.

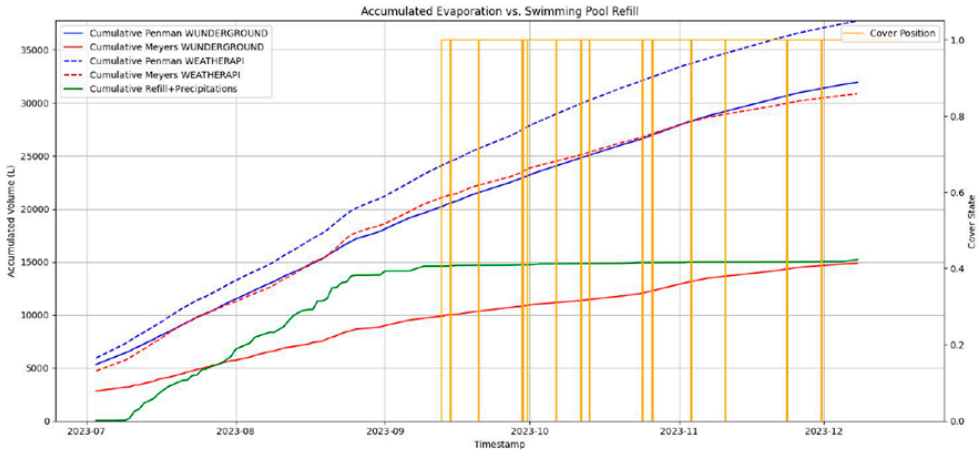

Figure 6. Hydric balance of installation 2 (cumulative values) (Source: Simulation values).

In the context of the outdoor swimming pool installations under study, it is important to mention the absence of water heating systems. This particularity means that the main energy requirement originates from the pumping process that is necessary for water filtration. Currently, a simulation of the energy consumption is being carried out and this simulation process is decisive for the identification of opportunities to improve the energy efficiency of outdoor swimming pool facilities.

Figure 7 shows the pool filtration energy consumption, in kWh, overlaid on the recirculation rate of the pool water through the filtration system, in number of recirculations.

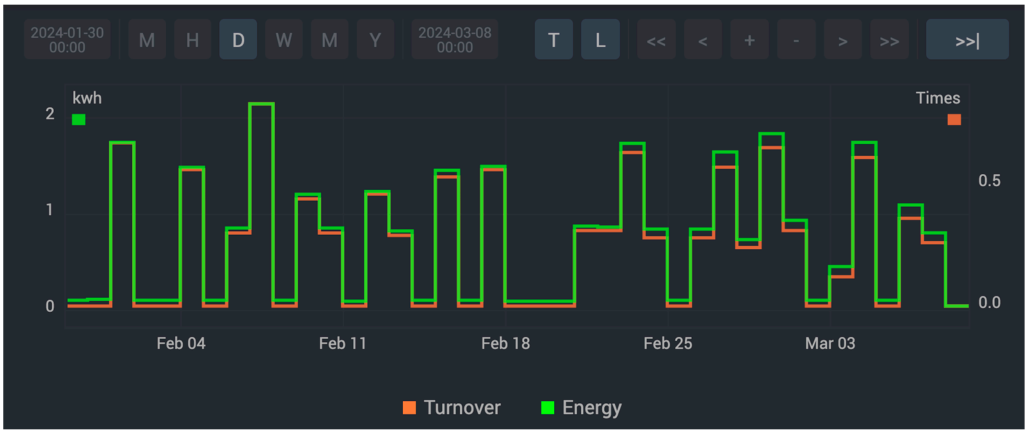

Figure 7. Energy balance of installation 1—comparison between installation energy consumption and turnover of water (Source: screen capture of simulation dashboard).

In this installation, the filtration pump has a frequency variator that allows the pump to adapt to the filtration needs, providing the necessary power for water filtration at all times and, therefore, adjusting the energy consumption to the needs of the installation.

Figure 8 shows the same graph as above, but for installation 2.

In this case, the installation's pump does not have a speed variation, so it works in an all-or-nothing regime. Therefore, it cannot adapt to the filtration needs and always works at maximum speed. This is sometimes not necessary, which means that energy consumption is higher in this case.

In the case of installation 3, it is experiencing certain technical problems that affect the quality and comparability of its data with respect to the other two installations. Consequently, corrective actions are being carried out with the aim of re-establishing the proper functioning of the installation, to ensure that the data collected are consistent and comparable with those obtained in the other two installations.

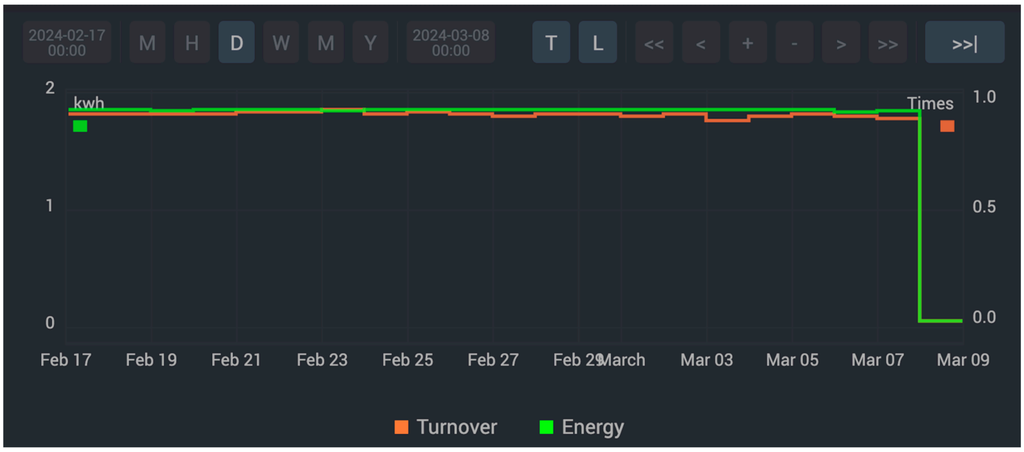

Figure 8. Energy balance of installation 2—comparison between installation energy consumption and turnover of water (Source: screen capture of simulation dashboard).

3. Results

In the water model described in Equation (2), where, on the one hand, we have the volumes of water that enter the pools to compensate for the various water loss variables and, thus, maintain the volume of water balanced, it is highlighted that the main indicators to be taken into account for the sustainability of the pools are the following: volume of water lost due to evaporation; volume of water lost during filter backwashing; and volume of water lost due to lack of watertightness of the pool shell or the pool's hydraulic system. The rest of the water loss variables are minor and, under normal conditions, do not represent a significant value with respect to these three indicators.

It is important to note that, depending on the specific characteristics of each installation, the critical variables may change, which underlines the importance of adapting the analysis to the particular conditions of each case.

Evaporation is one of the most important factors in water consumption in swimming pools, as evidenced in the scientific literature. This variable is identified as one of the main vectors of water loss, thus underlining its importance within the set of elements to be considered in efficient water management.

As far as water losses during backwashing are concerned, there are no academic studies that find a simulation equation, for this reason, and with the aim of being more efficient in the development of the research, it has been left for a later analysis.

An important case to analyze concerns water losses due to leaks in the system, which, if they occur, can be the main problem to tackle.

To address these factors, a number of potential solutions are already available in the pool market, including various filtration systems that do not require backwashing, such as regenerative media filters, ceramic filters, and other systems. In turn, to counteract water loss through evaporation, pool covers represent one of the most effective options. Consequently, monitored pools include both those equipped with covers and those without. In addition, automatic pool monitoring can quickly highlight any problems, allowing corrective action to be taken quickly and thus minimizing water loss.

In the energy model described above, there are major differences in the relevant variables between the two main types of swimming pools—indoor pools, which are usually equipped with heating systems, and outdoor pools, which usually do not have such a system. Therefore, the main variables for each system are as follows:

1. In heated indoor pools, the largest energy consumption is attributed to the water heating system described in Equation (6), where a steady-state installation, on one side of the equation, and the heat produced by the pool heating system offsetting, on the other side of the equation, all describe the various heat loss variables of the pool. This is a critical factor, as maintaining a comfortable pool water temperature

requires a significant amount of energy, especially in colder climates or during low temperature seasons.

2. On the other hand, in outdoor pools, where water heating systems are not usually used, the main energy consumer is the filtration system described in Equation (9), which describes the calculation of the power required by the filtration pump to recirculate the water, which is necessary for the correct treatment of the water. Filtration pumps are essential for maintaining water quality, removing impurities, and ensuring adequate sanitary conditions for users. However, these systems require a continuous use of energy to operate effectively.

Regarding the detailed interpretation of the data obtained from the evaporation simulation model in the monitored installations, it provides interesting results, especially in the cumulative data presented for the installations. Despite presenting similar characteristics, the analysis of the slopes in Figures 4 and 6, for installations 1 and 2, respectively, where we can see that the green curve, corresponding to the cumulative value of water input between the pool renovation refilling water and the rainwater collected on the surface of the pool, corresponds to the real water consumption. This value corresponds to the actual water consumption monitored to keep the installation in water balance and reveals that each installation experiences a different water consumption. This variability underlines the influence of the factors on water consumption, specific to each installation, that must be considered.

Finally, in the interpretation of the energy consumption data, Figures 7 and 8, for installations 1 and 2, respectively, where the energy consumption curves of the filtration pump are shown in superposition of the value of the number of water renewals for treatment. It can be seen that, in the case of installation 1, where the pump has a frequency variator that modifies the speed and, therefore, the power of the pump, adapting to the physical needs of the installation in terms of water treatment. In this installation the energy consumption is lower than in the case of installation 2, which does not have this technology.

This implicates that, in order to effectively assess the sustainability of swimming pool facilities, it is important to take into account facility-specific factors such as location, equipment, and use, as well as more unique factors. Adjusting the analysis to these individual aspects allows more precise and applicable sustainability strategies to be developed. In addition, establishing a model for swimming pools is essential for benchmarking sustainability assessments, providing a framework for identifying areas for improvement and tracking progress toward sustainability goals.

4. Discussion

Adapting swimming pools to the context of climate change is essential to ensure their sustainability. The focus on water savings and energy efficiency, based on an exploratory descriptive analysis, offers a viable framework for mitigating the environmental impacts associated with these infrastructures.

Evaporation, as can be seen in the model as well as in the academic literature analyzed, is a critical variable to be considered and there are solutions on the market to minimize it and, in the case of swimming pools outside the bathing season, almost eliminate it. This can be seen in the effectiveness of the pool cover in installation 2, which shows a significant impact on water conservation. Furthermore, after the end of the bathing season in mid-September and the permanent installation of the cover, the water consumption curve remains practically flat, showing a drastic reduction in water consumption. According to the monitoring data, the efficiency of the cover is estimated at 96% for this installation. In addition, this type of solution also significantly helps, in the case of pools with a heating system, to conserve the heat of the installation.

On the other hand, water consumption is differentiated between the two facilities and, despite having similar characteristics, it is revealed that each facility experiences different water consumption. This variability underlines the influence of facility-specific factors on water consumption and the location and use of the pool.

In addition to the effect of the cover, the off-season evaporation in installation 1, without this component should be considered, whereby a decrease in evaporation is noted outside the bathing season compared to the summer season. However, the absence of a cover results in continuous evaporative water losses throughout the year. The use of pool covers not only significantly reduces water consumption, but also improves running costs by minimizing the need for filtration and water treatment, thereby reducing the entrance of contaminants into the pool. This effect is particularly beneficial during the off-season, when most of the contaminants entering the pool come from the environment and the air.

The evaporation rate in both facilities is higher in the summer season (bathing season), with a steeper consumption curve during the summer months, which is attributed to an increase in evaporation, due to the favorable climatic conditions of this season. This is described in both equations used for the calculation of evaporation, where temperature significantly affects the evaporation rate of swimming pool water.

Furthermore, comparing the two formulas evaluated for the simulation of the evaporation rate—Penman and Meyer—it is inferred that the Meyer equation provides results that are more similar and consistent with the real data. This observation supports the validity of the Meyer equation for evaporation estimation under these specific conditions.

Finally, regarding the water balance, differences can be seen in the calculation of evaporation depending on the meteorological data used. There is a difference between the evaporation calculations made with data from the station installed on-site next to the pool and those obtained through Wunderground. This phenomenon may be due to the local climatic conditions generated by the pool, which may be difficult to replicate with generic data. Despite this, the resulting curves present a remarkable parallelism, suggesting the possibility of identifying a correlation variable that would allow the Wunderground data to be adjusted and used, according to the simulation objectives. This would open the door to estimating evaporation losses, independently of pool location, using Wunderground data.

Regarding the energy balance of the installations tested, it can be seen that the use of pumping frequency variation technologies, which allow the pump power to be adapted to the needs of the installation, is presented as a solution for reducing energy consumption in outdoor installations. Apart from this pumping speed variation technology, the rest of the installation parameters also affect the consumption variables.

Finally, improving water and energy sustainability is also crucial to improving the running costs of swimming pool facilities. All of these operational and cost improvements represent an opportunity for an improvement in hotel facilities, while increasing the sustainability and competitiveness of the installations [28,100–102].

5. Conclusions

In conclusion, the importance of adapting facility-specific strategies to optimize water and energy management should be emphasized, consequently enhancing the sustainability of monitored pools. Swimming pools can, and must, become more efficient, to adapt to the changing needs that arise with climate change. More specifically, the implementation of covers represents a practical solution, widely available in the market, to mitigate losses due to evaporation. Likewise, in the field of energy efficiency, the adoption of variable-speed motors is also crucial, allowing adaptation to the installation's demands and, thus, optimizing energy performance.

Furthermore, the discussion focuses on the feasibility of implementing these measures in the context of the Costa Brava, considering the economic, social, and environmental particularities of the region. The need for public policies that encourage the adoption of sustainable practices in the tourism sector is also debated.

One of the limitations of this study is that the evaporation model has been studied. In future lines of research, a more extensive simulation should be undertaken to study the interrelationships of the rest of the variables that will surely help in the decision making process for a more sustainable pool model. Furthermore, as explained in the results section, the design of the installation and its location are important variables when it comes to obtaining different results. For this reason, in future lines of research, a greater number of installations with different locations will be introduced and they will continue to be analyzed over time, to assess how the time variable affects their behavior.

This research represents an important tool for the improvement of the sustainability of aquatic swimming pool facilities that affects all stakeholders, although it is especially important for the owners of these facilities, also with, apart from the aforementioned improvements in the sustainability of the equipment, operational improvements of the same ilk. Improving sustainability is also an opportunity for governments to address the growing challenges of water and energy consumption, especially in tourist areas with a Mediterranean climate, which are magnified by the effects of climate change. Improving sustainability not only increases the competitiveness of the sector, but also represents an important opportunity for legislators to introduce legislation to improve facilities to make them more resource efficient. This legislative action can facilitate the transition to a more sustainable sector, which is very important for regions that are highly dependent on tourism, as is the case of Catalonia, where tourism accounts for up to 12% of the GDP generated [103].

Author Contributions: Conceptualization, J.-J.G.-G. and N.A.-S.; methodology, J.-J.G.-G. and N.A.-S.; investigation, J.-J.G.-G. and N.A.-S.; writing—original draft preparation, J.-J.G.-G. and N.A.-S.; supervision, J.-J.G.-G. and N.A.-S.; experiment preparation and data collection, J.-J.G.-G., D.T.B. and D.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research is part of an Industrial Doctorate funded by the Generalitat de Catalunya (Catalan government). File number 2020 DI 34.

Data Availability Statement: The datasets presented in this article are not available because they are part of a research project and are the property of the collaborating organization.

Conflicts of Interest: Authors David Tapias Baqué and David Giménez were employed by the company Fluidra. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Gössling, S.; Scott, D.; Hall, C.M. Pandemics, Tourism and Global Change: A Rapid Assessment of COVID-19. *J. Sustain. Tour.* **2020**, *29*, 1–20. [CrossRef]
2. Scott, D.; Gössling, S.; Hall, C.M. International Tourism and Climate Change. *Wiley Interdiscip. Rev. Clim. Chang.* **2012**, *3*, 213–232. [CrossRef]
3. Uzunlar, A.; Dis, M.O. Novel Approaches for the Empirical Assessment of Evapotranspiration over the Mediterranean Region. *Water* **2024**, *16*, 507. [CrossRef]
4. Saurí, D.; Olcina, J.; Vera, J.; Martin-Vide, J.; March, H.; Serra-Llobet, A.; Padilla, E. *Tourism, Climate Change and Water Resources: Coastal Mediterranean Spain as an Example*; Wiley: Hoboken, NJ, USA, 2013; pp. 231–252. ISBN 9780470977415.
5. World Tourism Organisation (UNWTO). UNWTO World Tourism Barometer. 2022. Available online: https://webunwto.s3.eu-west-1.amazonaws.com/s3fs-public/2022-09/UNWTO_Barom22_05_Sept_EXCERPT.pdf?VersionId=pYFmf7WMvpcfjUDuhNzbQ_G.4phQX79q (accessed on 12 June 2023).
6. Generalitat de Catalunya. *El Canvi Climàtic a Catalunya—3er Informe Sobre El Canvi Climàtic a Catalunya; Barcelona, Spain*; 2017. Available online: https://canviclimatic.gencat.cat/web/.content/03_AMBITS/adaptacio/Informes_del_canvi_climatic_a_catalunya/WEB_RESUM_EXECUTIU_2017.pdf (accessed on 7 January 2024).
7. Mellou, K.; Mplougoura, A.; Mandilara, G.; Papadakis, A.; Chochlakis, D.; Psaroulaki, A.; Mavridou, A. Swimming Pool Regulations in the COVID-19 Era: Assessing Acceptability and Compliance in Greek Hotels in Two Consecutive Summer Touristic Periods. *Water* **2022**, *14*, 796. [CrossRef]
8. Villar-Navascués, R.A.; Pérez-Morales, A. Factors Affecting Domestic Water Consumption on the Spanish Mediterranean Coastline. *Prof. Geogr.* **2018**, *70*, 513–525. [CrossRef]
9. Mendoza, E.; Ferrero, G.; Slokar, Y.M.; Amores, X.; Azzellino, A.; Buttiglieri, G. Water Management Practices in Euro-Mediterranean Hotels and Resorts. *Int. J. Water Resour. Dev.* **2023**, *39*, 485–506. [CrossRef]
10. Iraldo, F.; Nucci, B. Proactive Environmental Management in Hotels: What Difference Does It Make? *Econ. Policy Energy Environ.* **2016**, *2016*, 81–106. [CrossRef]

11. Sun, R.; Gao, J. Theories Study of Modelling Tourism Impacts on Coastal Environment. *Adv. Mater. Res.* **2012**, *573*, 358–361, ISBN 9783037854952. [CrossRef]
12. Puig, R.; Kiliç, E.; Navarro, A.; Albertí, J.; Chacón, L.; Fullana-i-Palmer, P. Inventory Analysis and Carbon Footprint of Coastland-Hotel Services: A Spanish Case Study. *Sci. Total. Environ.* **2017**, *595*, 244–254. [CrossRef]
13. Kiper, V.O.; Sarac, O.; Batman, O. Drought Tourism: Adopting Tourism for Water Scarcity. In *Reviving Tourism in the Post-Pandemic Era*; Christou, E., Fotiadis, A., Eds.; School of Economics and Business, International Hellenic University: Nea Moudania, Greece, 2022; pp. 531–541. ISBN 9786185630065.
14. Saló, A.; Garriga, A.; Rigall-I-Torrent, R.; Vila, M.; Fluvià, M. Do Implicit Prices for Hotels and Second Homes Show Differences in Tourists' Valuation for Public Attributes for Each Type of Accommodation Facility? *Int. J. Hosp. Manag.* **2014**, *36*, 120–129. [CrossRef]
15. Soifer, I.; Choi, E.-K.; Lee, E. Do Hotel Attributes and Amenities Affect Online User Ratings Differently across Hotel Star Ratings? *J. Qual. Assur. Hosp. Tour.* **2021**, *22*, 539–560. [CrossRef]
16. Bočkus, D.; Tammi, T.; Vento, E.; Komppula, R. Wellness Tourism Service Preferences and Their Linkages to Motivational Factors: A Multiple Case Study. *Int. J. Spa Wellness* **2023**, *6*, 78–108. [CrossRef]
17. Heilgeist, S.; Sahin, O.; Sekine, R.; Stewart, R.A. Mapping the Complex Journey of Swimming Pool Contaminants: A Multi-Method Systems Approach. *Water* **2022**, *14*, 2062. [CrossRef]
18. Al Khatib, I.A.; Ghannam, R.S. Microbiological Water Quality and Sampling Policy of Public Swimming Pools. *Int. J. Environ. Eng.* **2011**, *3*, 192. [CrossRef]
19. Ministerio de Sanidad, Servicios Sociales e Igualdad. Gobierno de España; Real Decreto 742/2013, de 27 de Septiembre, Por El Que Se Establecen Los Criterios Técnico-Sanitarios de Las Piscinas. Available online: https://www.boe.es/buscar/pdf/2013/BOE-A-2013-10580-consolidado.pdf (accessed on 13 July 2023).
20. Gallion, T.; Harrison, T.; Hulverson, R.; Hristovski, K. Estimating Water, Energy, and Carbon Footprints of Residential Swimming Pools. In *Water Reclamation and Sustainability*; Elsevier Inc.: Amsterdam, The Netherlands, 2014; pp. 343–359. ISBN 9780124165762.
21. Rico, A.; Martínez-Blanco, J.; Montlleó, M.; Rodríguez, G.; Tavares, N.; Arias, A.; Oliver-Solà, J. Carbon Footprint of Tourism in Barcelona. *Tour. Manag.* **2019**, *70*, 491–504. [CrossRef]
22. Díaz Pérez, F.J.; Chinarro, D.; Guardiola Mouhaffel, A.; Díaz Martín, R.; Pino Otín, M. ªR Comparative Study of Carbon Footprint of Energy and Water in Hotels of Canary Islands Regarding Mainland Spain. *Environ. Dev. Sustain.* **2019**, *21*, 1763–1780. [CrossRef]
23. Generatlitat de Catalunya Resolució ACC/220/2024, d'1 de Febrer, per La Qual Es Declara L'estat D'emergència I per Sequera Hidrològica a Les Unitats d'explotació Embassaments Del Ter-Llobregat, Embassaments Del Ter i Embassaments Del Llobregat, Es Declara La Sortida D'alerta de La Unitat D'explotació Del Consorci d'Aigües de Tarragona i S'actualitzen Diversos Estats de Sequera Pluviomètrica. Available online: https://dogc.gencat.cat/ca/document-del-dogc/?documentId=977626 (accessed on 2 March 2024).
24. Generalitat de Catalunya (Agència Catalana de l'Aigua) El Visor de La Sequera. Available online: https://aplicacions.aca.gencat.cat/visseq/estat-actual (accessed on 2 March 2024).
25. Pisano, A.; Marullo, S.; Artale, V.; Falcini, F.; Yang, C.; Leonelli, F.E.; Santoleri, R.; Nardelli, B.B. New Evidence of Mediterranean Climate Change and Variability from Sea Surface Temperature Observations. *Remote Sens.* **2020**, *12*, 132. [CrossRef]
26. Tramblay, Y.; Llasat, M.C.; Randin, C.; Coppola, E. Climate Change Impacts on Water Resources in the Mediterranean. *Reg. Environ. Chang.* **2020**, *20*, 83. [CrossRef]
27. Tramblay, Y.; Koutroulis, A.; Samaniego, L.; Vicente-Serrano, S.M.; Volaire, F.; Boone, A.; Le Page, M.; Llasat, M.C.; Albergel, C.; Burak, S.; et al. Challenges for Drought Assessment in the Mediterranean Region under Future Climate Scenarios. *Earth Sci. Rev.* **2020**, *210*, 103348. [CrossRef]
28. Marinopoulos, I.S.; Katsifarakis, K.L. Optimization of Energy and Water Management of Swimming Pools. A Case Study in Thessaloniki, Greece. *Procedia Environ. Sci.* **2017**, *38*, 773–780. [CrossRef]
29. Doménech-Sánchez, A.; Laso, E.; Berrocal, C.I. Water Loss in Swimming Pool Filter Backwashing Processes in the Balearic Islands (Spain). *Water Policy* **2021**, *23*, 1314–1328. [CrossRef]
30. Mancic, M.V.; Zivkovic, D.S.; Djordjevic, M.L.; Jovanovic, M.S.; Rajic, M.N.; Mitrovic, D.M. Techno-economic optimization of configuration and capacity of a polygeneration system for the energy demands of a public swimming pool building. *Thermal. Sci.* **2018**, *22*, S1535–S1549. [CrossRef]
31. Li, Y.; Nord, N.; Huang, G.; Li, X. Swimming Pool Heating Technology: A State-of-the-Art Review. *Build. Simul.* **2021**, *14*, 421–440. [CrossRef]
32. Generalitat de Catalunya DECRET 165/2001, de 12 de Juny, de Modificació Del Decret 95/2000, de 22 de Febrer, Pel Qual s'estableixen Les Normes Sanitàries Aplicables a Les Piscines d'ús Públic. Available online: https://portaljuridic.gencat.cat/ca/document-del-pjur/?documentId=260850 (accessed on 13 July 2023).
33. Generalitat de Catalunya DECRET 95/2000, de 22 de Febrer, Pel Qual s'estableixen Les Normes Sanitàries Aplicables a Les Piscines d'ús Públic. Available online: https://portaljuridic.gencat.cat/eli/es-ct/d/2000/02/22/95 (accessed on 13 July 2023).
34. Generalitat de Catalunya DECRET 177/2000, de 15 de Maig, Pel Qual Es Modifica La Disposició Transitòria Única Del Decret 95/2000, de 22 de Febrer, Pel Qual s'estableixen Les Normes Sanitàries Aplicables a Les Piscines d'ús Públic. Available online: https://portaljuridic.gencat.cat/ca/document-del-pjur/?documentId=229596 (accessed on 13 July 2023).

35. Lugo, S.; Morales, L.I.; Best, R.; Gómez, V.H.; García-Valladares, O. Numerical Simulation and Experimental Validation of an Outdoor-Swimming-Pool Solar Heating System in Warm Climates. *Sol. Energy* **2019**, *189*, 45–56. [CrossRef]
36. Pérez-Carramiñana, C.; Maciá-Mateu, A.; Sirvent-García, G.; Lledó-Llorca, I. Study of Natural Ventilation and Solar Control Strategies to Improve Energy Efficiency and Environmental Quality in Glazed Heated Swimming Pools in a Dry Mediterranean Climate. *Sustainability* **2022**, *14*, 8243. [CrossRef]
37. Lam, J.C.; Chan, W.W. Life Cycle Energy Cost Analysis of Heat Pump Application for Hotel Swimming Pools. *Energy Convers. Manag.* **2001**, *42*, 1299–1306. [CrossRef]
38. Floričić, T. Sustainable Solutions in the Hospitality Industry and Competitiveness Context of "Green Hotels". *Civ. Eng. J.* **2020**, *6*, 1104–1113. [CrossRef]
39. Bagur-Femenias, L.; Celma, D.; Patau, J. The Adoption of Environmental Practices in Small Hotels. Voluntary or Mandatory? An Empirical Approach. *Sustainability* **2016**, *8*, 695. [CrossRef]
40. Kular, N.K. Energy Conservation in Hotels: A Green Approach. In *Managing Sustainability in the Hospitality and Tourism Industry*; Apple Academic Press: Palm Bay, FL, USA, 2014; ISBN 9781482223569.
41. Khatter, A.; McGrath, M.; Pyke, J.; White, L.; Lockstone-Binney, L. Analysis of Hotels' Environmentally Sustainable Policies and Practices: Sustainability and Corporate Social Responsibility in Hospitality and Tourism. *Int. J. Contemp. Hosp. Manag.* **2019**, *31*, 2394–2410. [CrossRef]
42. Hof, A.; Moran-Tejeda, E.; Lorenzo-Lacruz, J.; Blazquez-Salom, M. Swimming Pool Evaporative Water Loss and Water Use in the Balearic Islands (Spain). *Water* **2018**, *10*, 1883. [CrossRef]
43. Gómez Martínez, G.; Pérez Martín, M.Á. Water Management Adaptation to Climate Change in Mediterranean Semiarid Regions by Desalination and Photovoltaic Solar Energy, Spain. *Water* **2023**, *15*, 3239. [CrossRef]
44. Lenzen, M.; Sun, Y.-Y.; Faturay, F.; Ting, Y.-P.; Geschke, A.; Malik, A. The Carbon Footprint of Global Tourism. *Nat. Clim. Chang.* **2018**, *8*, 522–528. [CrossRef]
45. María del Rosario, R.S.; Patricia S., S.M.; René, D.P. Eco-Innovation and Organizational Culture in the Hotel Industry. *Int. J. Hosp. Manag.* **2017**, *65*, 71–80. [CrossRef]
46. Legrand, W.; Dubrocard, N. Freshwater and Waste Water Management in Mediterranean Hotels and Resorts: Owner-Operator Issues. In *Sustainable Tourism Practices in the Mediterranean*; Routledge: London, UK, 2019; ISBN 978-1-351-59956-6.
47. Gössling, S. New Performance Indicators for Water Management in Tourism. *Tour. Manag.* **2015**, *46*, 233–244. [CrossRef]
48. Page, S.J.; Essex, S.; Causevic, S. Tourist Attitudes towards Water Use in the Developing World: A Comparative Analysis. *Tour. Manag. Perspect.* **2014**, *10*, 57–67. [CrossRef]
49. Forrest, N.; Williams, E. Life Cycle Environmental Implications of Residential Swimming Pools. *Environ. Sci. Technol.* **2010**, *44*, 5601–5607. [CrossRef]
50. Shah, M.M. Improved Model for Calculation of Evaporation from Water Pools. *Sci. Technol. Built. Environ.* **2018**, *24*, 1064–1074. [CrossRef]
51. Shah, M.M. Evaluation of Methods for Prediction of Evaporation from Water Pools. *J. Build. Phys.* **2022**, *45*, 629–648. [CrossRef]
52. Shah, M.M. Further Development and Verification of the Model for Evaporation from Pools. *Sci. Technol. Built. Environ.* **2023**, *29*, 75–85. [CrossRef]
53. Smith, C.C.; Loef, G.O.G.; Jones, R.W. *Rates of Evaporation from Swimming Pools in Active*; ASHRAE: Peachtree Corners, GA, USA, 1999.
54. Linacre, E.T. A Simple Formula for Estimating Evaporation Rates in Various Climates, Using Temperature Data Alone. *Agric. Meteorol.* **1977**, *18*, 409–424. [CrossRef]
55. Meyer, A.F. Computing Runoff from Rainfall and Other Physical Data. *Trans. Am. Soc. Civ. Eng.* **1915**, *79*, 1056–1224. [CrossRef]
56. Penman, H.L. Natural Evaporation from Open Water, Bare Soil and Grass. *Proc. R. Soc. Lond. A Math. Phys. Sci.* **1948**, *193*, 120–145. [CrossRef]
57. Cloteaux, A.; Gérardin, F.; Midoux, N. Influence of Swimming Pool Design on Hydraulic Behavior: A Numerical and Experimental Study. *Engineering* **2013**, *5*, 511–524. [CrossRef]
58. Dougha, M.; Hasbaia, M.; Girou, A.; Redjem, A. Analysis of Numerical Simulation of the Hydrodynamics in Swimming Pools, in Terms of Water Quality. *EuroMediterr. J. Environ. Integr.* **2018**, *3*, 33. [CrossRef]
59. Golbaz, S.; Nabizadeh, R.; Zarinkolah, S.; Mahvi, A.H.; Alimohammadi, M.; Yousefi, M. An Innovative Swimming Pool Water Quality Index (SPWQI) to Monitor and Evaluate the Pools: Design and Compilation of Computational Model. *Environ. Monit. Assess.* **2019**, *191*, 448. [CrossRef]
60. Orlov, V.; Zotkin, S.; Pelipenko, A. Mathematical Modelling of Water Exchange in Public Swimming Pools. *Proc. IOP Conf. Ser. Mater. Sci. Eng.* **2018**, *365*, 042016. [CrossRef]
61. Zhang, J.; Sinha, N.; Ross, M.; Tejada-Martínez, A.E. Computational Fluid Dynamics Analysis of the Hydraulic (Filtration) Efficiency of a Residential Swimming Pool. *J. Water Health* **2018**, *16*, 750–761. [CrossRef]
62. Mak, A.H.N.; Chang, R.C.Y. The Driving and Restraining Forces for Environmental Strategy Adoption in the Hotel Industry: A Force Field Analysis Approach. *Tour. Manag.* **2019**, *73*, 48–60. [CrossRef]
63. Aldarabseh, S.M.; Merati, P. Experimental Investigation of the Effects of Intermediate Gravity Waves on the Water Evaporation Rate. *J. Therm Sci. Eng. Appl.* **2022**, *14*, 081011. [CrossRef]

64. Ciuman, P.; Lipska, B. Experimental Validation of the Numerical Model of Air, Heat and Moisture Flow in an Indoor Swimming Pool. *Build. Environ.* **2018**, *145*, 1–13. [CrossRef]
65. Foncubierta Blázquez, J.L.; Maestre, I.R.; González Gallero, F.J.; Álvarez Gómez, P. Experimental Test for the Estimation of the Evaporation Rate in Indoor Swimming Pools: Validation of a New CFD-Based Simulation Methodology. *Build. Environ.* **2018**, *138*, 293–299. [CrossRef]
66. Foncubierta Blázquez, J.L.; Maestre, I.R.; González Gallero, F.J.; Pérez-Lombard, L.; Bottarelli, M. Experimental Adjustment of the Turbulent Schmidt Number to Model the Evaporation Rate of Swimming Pools in CFD Programmes. *Case Stud. Therm. Eng.* **2023**, *41*, 102665. [CrossRef]
67. Gallero, F.J.G.; Maestre, I.R.; Foncubierta Blázquez, J.L.; Mena Baladés, J.D. Enhanced CFD-Based Approach to Calculate the Evaporation Rate in Swimming Pools. *Sci. Technol. Built. Environ.* **2020**, *27*, 524–532. [CrossRef]
68. Liew, C.S.M.; Li, X.; Zhang, H.; Lee, H.K. A Fully Automated Analytical Platform Integrating Water Sampling-Miniscale-Liquid-Liquid Extraction-Full Evaporation Dynamic Headspace Concentration-Gas Chromatography-Mass Spectrometry for the Analysis of Ultraviolet Filters. *Anal. Chim. Acta* **2018**, *1006*, 33–41. [CrossRef] [PubMed]
69. Smedegård, O.O.; Aas, B.; Stene, J.; Georges, L. Measurement and Analysis of Evaporation in Indoor Swimming Pools: Comparison with the ASHRAE' s Activity Factor. In Proceedings of the E3S Web of Conferences, Semarang, Indonesia, 9–10 August 2022; Volume 362.
70. Alansari, A.; Amburgey, J.; Madding, N. A Quantitative Analysis of Swimming Pool Recirculation System Efficiency. *J. Water Health* **2018**, *16*, 449–459. [CrossRef] [PubMed]
71. Wyczarska-Kokot, J.; Dudziak, M. Reuse-Reduce-Recycle: Water and Wastewater Management in Swimming Pool Facilities. *Desalination Water Treat.* **2022**, *275*, 69–80. [CrossRef]
72. Wyczarska-Kokot, J.; Lempart, A. The influence of the filtration bed type in the pool water treatment system on washings quality. *Ecol. Chem. Eng. S-Chem. I Inz. Ekol. S* **2019**, *26*, 535–545. [CrossRef]
73. Chen, Z.; Ngo, H.H.; Guo, W.; Lim, R.; Wang, X.C.; O'Halloran, K.; Listowski, A.; Corby, N.; Miechel, C. A Comprehensive Framework for the Assessment of New End Uses in Recycled Water Schemes. *Sci. Total. Environ.* **2014**, *470–471*, 44–52. [CrossRef] [PubMed]
74. Poćwiardowski, W. The Potential of Swimming Pool Rinsing Water for Irrigation of Green Areas: A Case Study. *Environ. Sci. Pollut. Res.* **2023**, *30*, 57174–57177. [CrossRef] [PubMed]
75. Studziński, W.; Poćwiardowski, W.; Osińska, W. Application of the Swimming Pool Backwash Water Recovery System with the Use of Filter Tubes. *Molecules* **2021**, *26*, 6620. [CrossRef] [PubMed]
76. Wyczarska-Kokot, J.; Lempart, A. The reuse of washings from pool filtration plants after the use of simple purification processes. *Archit. Civ. Eng. Environ.* **2018**, *11*, 163–170. [CrossRef]
77. Ribeiro, E.; Jorge, H.M.; Quintela, D.A. HVAC system energy optimization in indoor swimming pools. In Proceedings of the 2011 3rd International Youth Conference on Energetics (IYCE), Leiria, Portugal, 7–9 July 2011; p. 7.
78. Ilgaz, R.; Yumrutas, R. Heating Performance of Swimming Pool Incorporated Solar Assisted Heat Pump and Underground Thermal Energy Storage Tank: A Case Study. *Int. J. Energy Res.* **2022**, *46*, 1008–1031. [CrossRef]
79. Al-Falahat, A.; Abu, Q.; Alrwashdeh, S. Economic Feasibility of Heating Source Conversion of the Swimming Pools. *J. Appl. Eng. Sci.* **2022**, *20*, 230–238. [CrossRef]
80. Chow, T.T.; Bai, Y.; Fong, K.F.; Lin, Z. Analysis of a Solar Assisted Heat Pump System for Indoor Swimming Pool Water and Space Heating. *Appl. Energy* **2012**, *100*, 309–317. [CrossRef]
81. Xu, Y.C.; Guo, Z.W.; Yuan, C.Q. Feasibility Study of an Integrated Air Source Heat Pump Water Heater/Chillers and Exhaust Gas Boiler Heating System for Swimming Pool on Luxury Cruise Ship. *Energy Rep.* **2022**, *8*, 1260–1282. [CrossRef]
82. Santos, E.T.; Zárate, L.E.; Pereira, E.M.D. Hybrid Thermal Model for Swimming Pools Based on Artificial Neural Networks for Southeast Region of Brazil. *Expert Syst. Appl.* **2013**, *40*, 3106–3120. [CrossRef]
83. Mančić, M.; Živković, D.; Laković Paunović, M.; Mančić, M.; Rajic, M. Experimental Evaluation of Correlations of Evaporation Rates from Free Water Surfaces of Indoor Swimming Pools. In *Experimental and Computational Investigations in Engineering: Proceedings of the International Conference of Experimental and Numerical Investigations and New Technologies, CNNTech 2020*; Springer International Publishing: Cham, Switzerland, 2021; Volume 153, pp. 378–393.
84. Mančić, M.V.; Živković, D.S.; Milosavljević, P.M.; Todorović, M.N. Mathematical Modelling and Simulation of the Thermal Performance of a Solar Heated Indoor Swimming Pool. *Therm. Sci.* **2014**, *18*, 999–1010. [CrossRef]
85. Delgado Marín, J.P.; Vera García, F.; García Cascales, J.R. Use of a Predictive Control to Improve the Energy Efficiency in Indoor Swimming Pools Using Solar Thermal Energy. *Sol. Energy* **2019**, *179*, 380–390. [CrossRef]
86. Calise, F.; Figaj, R.; Vanoli, L. Energy and Economic Analysis of Energy Savings Measures in a Swimming Pool Centre by Means of Dynamic Simulations. *Energy* **2018**, *11*, 2182. [CrossRef]
87. Lau, M.J.; Zanil, M.F.; Choong, S.Y.; Tan, J. Modelling and Optimization of the Heat Pump System for the Usage of Swimming Pool. *Proc. IOP Conf. Ser. Mater. Sci. Eng.* **2020**, *778*, 012097. [CrossRef]
88. Limane, A.; Fellouah, H.; Galanis, N. Three-Dimensional OpenFOAM Simulation to Evaluate the Thermal Comfort of Occupants, Indoor Air Quality and Heat Losses inside an Indoor Swimming Pool. *Energy Build.* **2018**, *167*, 49–68. [CrossRef]
89. Marin, J.P.D.; Garcia-Cuscales, J.R. Dynamic Simulation Model and Empirical Validation for Estimating Thermal Energy Demand in Indoor Swimming Pools. *Energy Effic.* **2020**, *13*, 955–970. [CrossRef]

90. Smedegård, O.Ø.; Aas, B.; Stene, J.; Georges, L.; Carlucci, S. Systematic and Data-Driven Literature Review of the Energy and Indoor Environmental Performance of Swimming Facilities. *Energy Effic.* **2021**, *14*, 74. [CrossRef]
91. Pop, O.; Pop, I. Solar water heating for a swimming pool. *Acta Tech. Napoc. Ser.-Appl. Math. Mech. Eng.* **2018**, *61*, 279–286.
92. Singh, A.K.; Tiwari, G.N.; Singh, R.G.; Singh, R.K. Active Heating of Outdoor Swimming Pool Water Using Different Solar Collector Systems. *J. Sol. Energy Eng.-Trans. ASME* **2020**, *142*, 041008. [CrossRef]
93. Wache, R.; Fielder, T.; Dickinson, W.E.C.; Hall, J.L.; Adlington, P.; Sweeney, S.J.; Clowes, S.K. Selective Light Transmission as a Leading Innovation for Solar Swimming Pool Covers. *Solar Energy* **2020**, *207*, 388–397. [CrossRef]
94. Zhao, J.; Bilbao, J.I.; Spooner, E.D.; Sproul, A.B. Experimental Study of a Solar Pool Heating System under Lower Flow and Low Pump Speed Conditions. *Renew. Energy* **2018**, *119*, 320–335. [CrossRef]
95. Sakshi; Shashi; Cerchione, R.; Bansal, H. Measuring the Impact of Sustainability Policy and Practices in Tourism and Hospitality Industry. *Bus. Strategy Environ.* **2020**, *29*, 1109–1126. [CrossRef]
96. Santos, E.; Lisboa, I.; Crespo, C.; Moreira, J.; Eugenio, T. Evaluating Economic Sustainability of Nautical Tourism through Brand Equity and Corporate Performance. In *Springer Proceedings in Business and Economics*; Springer International Publishing: Cham, Switzerland, 2022; pp. 105–118.
97. Redondo Alamillos, R.; de Mariz, F. How Can European Regulation on ESG Impact Business Globally? *J. Risk Financ. Manag.* **2022**, *15*, 291. [CrossRef]
98. Perales Viscasillas, P. Impacto de La Lucha Contra El Cambio Climático En El Gobierno Corporativo. In *Revista de Derecho del Sistema Financiero: Mercados, Operadores y Contratos*; Dialnet: Logroño, Spain, 2023; pp. 11–66. [CrossRef]
99. Krstinić Nižić, M.; Šverko Grdić, Z.; Endres, R. Energy Sustainability and Its Impacts on Croatian Tourism. *Croat. Econ. Surv.* **2017**, *19*, 83–104. [CrossRef]
100. Lewis, L.; Chew, J.; Woodley, I.; Colbourne, J.; Pond, K. Modifications for Water Management Guidance Based on an Assessment of Swimming Pool Water Consumption of an Operational Facility in the UK. *Water Sci. Technol. Water Supply* **2015**, *15*, 965–973. [CrossRef]
101. Osiako, P.O.; Kummitha, H.R. Environmental Management Practices among Coastal Beach Hotels in Kenya. *Afr. J. Hosp. Tour. Leis.* **2020**, *9*, 1–18.
102. Katsaprakakis, D. Al Comparison of Swimming Pools Alternative Passive and Active Heating Systems Based on Renewable Energy Sources in Southern Europe. *Energy* **2015**, *81*, 738–753. [CrossRef]
103. Generalitat de Catalunya El Nou Pla Estratègic de Turisme 2018–2022 Promou Un Model Turístic Català Intel·Ligent i Sostenible. Available online: https://govern.cat/salapremsa/notes-premsa/362742/nou-pla-estrategic-turisme-2018-2022-promou-model-turistic-catala-intel-ligent-sostenible (accessed on 9 March 2024).